VOLUME VIII. NUMBER 6

THE JOURNAL
OF
THE ROYAL ASTRONOMICAL SOCIETY OF CANADA

DEVOTED TO THE ADVANCEMENT OF ASTRONOMY AND ALLIED SCIENCES

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PUBLISHED BI-MONTHLY

NOVEMBER–DECEMBER, 1914

PRINTED FOR THE SOCIETY
TORONTO: 198 COLLEGE ST.
FOREIGN AGENTS: WILLIAM WESLEY & SON,
28 ESSEX ST., STRAND, LONDON.

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THE GREAT DISC FOR THE 72-INCH CANADIAN REFLECTOR
WITH DR. JOHN A. BRASHEAR BESIDE IT

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DEFORMATION OF THE EARTH BY THE MOON.

BY OTTO KLOTZ

IN chapter VI. of "The Tides" by Sir George Darwin he discusses the deflection of the vertical by the tide-generating force of the moon. In 1879, in conjunction with his brother Horace, he attempted to measure the microscopic movement of a pendulum under the influence of the lunar attraction. The difficulties encountered "led us to abandon our attempted measurement, and to conclude that all endeavors in that direction were doomed to remain forever fruitless. I can but hope that a falsification of our forecast by M. Ehlert and by others may be confirmed." This is the concluding paragraph in that chapter, and the forecast, as we know, has been disproved, first by the observation of Hecker; later by Orlov, Michelson and others.

If the earth were perfectly plastic then there would be no oceanic tides relative to the land, for both would be deformed equally and tide gauges would record no rising or falling of the water. On the other hand if the earth were perfectly rigid then we would have the greatest effect of oceanic tides by the lunar attraction. As the earth occupies a condition intermediate

between perfect plasticity and perfect rigidity, the ocean tides are considerably modified thereby. Darwin gives the intensity of the maximum horizontal force due to the moon compared with gravity as 1 to 11,660,000. As is seen, this is a very small quantity, and the difficulty of observing or determining it is manifest.

We will attempt to give an elementary exposition of observing the effect of lunar attraction in the solid earth by means of the horizontal pendulum and evaluating the recorded results. In outline the horizontal pendulum is simply a bob supported at one end of a horizontal boom, the other end being movable at a steel point resting in an agate cup, while fine wires support the bob from a point on a vertical rod. Now this latter point is not quite vertically above the lower point, and therein lies the merit of the horizontal pendulum. If the axis of rotation were vertical, then the pendulum would not oscillate when displaced from any position it might occupy. However, as soon as this axis is inclined to the bob, the pendulum will oscillate when displaced from its zero position, and the period of its oscillation, that is the time required to make a to-and-fro movement, will be dependent upon this inclination of the axis. The period is a function of the angle of inclination to the vertical. This angle is a matter of instrumental adjustment, so that we can give the pendulum a definite period of oscillation to suit our purpose of investigation. If, for instance, its period is 10 seconds for a single vibration, this would be equivalent to an ordinary pendulum hanging vertically as in a clock, of approximately 100 metres in length, or say 330 feet. Expressed in this manner one sees what a very small force indeed would be required to deflect the latter pendulum from its vertical position. Now this deflection we could accomplish, too, by tilting the support on which the pendulum hangs, that is, if the surface of the earth suffered a tilting or inclination to the horizontal the vertical pendulum would move through the same angular measure, and the longer the pendulum the more easily could we measure the linear displacement. With the above equivalent 100-metre pendulum we would

have a maximum deflection of the 11,660,000th part, or a little less than one hundredth of a millimetre. Knowing the mass and distance of the moon, as well as the intensity of gravity it is a simple mathematical problem to calculate the deflection of the vertical at any time for a rigid earth.

The physical tides of the earth follow the apparent motion of the moon, and hence the deflection of the pendulum has a to-and-fro movement under the lunar attraction twice a day, and with far greater regularity than obtains with the ocean tides, which are impeded in their onward course by the configuration of the earth's surface, *i.e.*, by the continents.

We are speaking only of the lunar attraction, while there is, too, one due to the sun, but as the former preponderates, in the ratio of about 7 to 3, we refer only to the former, although the latter is considered, and enters into any observation as well as into the final computation and reduction.

If then the theoretical deflection, on the supposition of an unyielding earth can be computed, and the actual deflection of the vertical under lunar attraction can be observed, it necessarily follows that we have the data for determining the 'give', the yielding, the rigidity of the earth, — a value of the utmost significance in geophysics.

It may be proper to state here, although it will be referred to later, that observations to measure the deflection are subject to certain indirect effects, amongst which may be mentioned the daily heating of the earth by the sun, whereby a bulging of the earth's surface, following the sun, is caused and a consequent tilting or deflection of the pendulum. This may amount to many times, — as much as 50 times — the gravitational effect of the sun. Again if the pendulum is mounted say within a hundred miles or even more of the sea-coast, the ocean tides exercise a dual influence. In the first place high tides loading the sea-shore, bend it, and the degree is dependent upon the elasticity of the rock subjected to the pressure. This effect, making plausible assumptions, admits of approximate estimate. Then again the mass of water brought in by high tide exerts a

gravitational effect on our pendulum just as the moon does and helps to mask the true lunar effect. The bending of the earth's crust, however, under the superimposed water-mass is, for near-coast stations of far greater effect than the gravitational one of the same mass. The two latter would snychronize with each other but not with the solar heating effect. The further we advance with the problem of measuring the deflection of the vertical by lunar attraction the more complicated and difficult of realization it becomes. Low tide, due to the withdrawal of water, has of course the opposite effect to high tide.

In the following we have followed with some modification Hecker's chapter XI. in Galitzin's "Seismometrie."

In general the plumb line is normal or vertical to the surface of the earth. However, under the attractive influence of a heavenly body it suffers a slight deviation and makes an angle $90° - \psi$ with the horizon, which is equivalent to an inclination of the horizon by the very small angle ψ.

If in a horizontal pendulum we let i be the angle which its axis of rotation makes with the vertical, and ψ the inclination the surface of the earth makes about an axis parallel to the arm of the pendulum, then the angle of deflection of the pendulum θ, will be expressed by $\theta = \frac{\psi}{i}$, all the angles being very small.

It has already been stated that i may be determined by observation of the period of the pendulum. As the movement or displacement of the pendulum is so minute, recourse is had to a small silver mirror situate in the axis of rotation for obtaining a desired magnification by means of a beam of light reflected to a recording drum. If y be the deflection of the image on the drum from its normal position and A the distance of the mirror from the drum then

$$\theta = \frac{y}{2A}.$$

Substituting this in the above equation we obtain

$$\psi = \frac{i}{2A} y.$$

From this formula we can evaluate ψ from the observations. In order to be able to measure y it is necessary to have a zero or base line, as in a photographic recording magnetograph, which is obtained from a fixed mirror on the pendulum frame. For the registrations on the drum a far lower speed is required than suffices for seismograms.

In the accompanying diagram (Figure 1) let AM represent the vertical on a rigid earth, due to the earth's attraction and rotation; and let AB represent its direction under the added

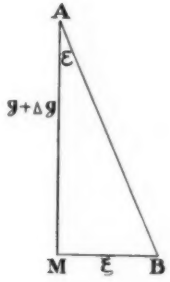


FIGURE 1

attractive influence of the moon, whereof Δg is the vertical and ξ the horizontal component, g representing terrestrial gravity. If ϵ be the angle which the position AB makes with the normal AM, then

$$\tan \epsilon = \frac{\xi}{g + \Delta g}, \text{ or as } \xi \text{ and } \Delta g \text{ are small}$$

$$\epsilon = \frac{\xi}{g}.$$

We shall now compute ξ.

In the figure, (Figure 2.) let T be the centre of the earth, M the place of observation, Z its zenith, L the position of the moon, z_1 and z the observed and geocentric zenith distances of the moon, similarly r_1 and r the distances.

In computing ξ it must be remembered that the moon attracts the earth as well as the pendulum, and if the attraction

at M were the same as at T, there would be no relative acceleration, that is, no deflection of the vertical at M.

If m denote the mass of the moon, unity that of the earth, and f the gravitational constant, then from Newton's law of

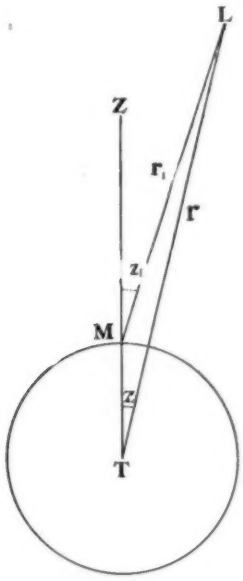


FIGURE 2

gravitation it follows that for the horizontal component of the attracting force at the surface of the earth,

$$\xi = f \frac{m}{r_1^2} \sin z_1 - f \frac{m}{r^2} \sin z \qquad (1)$$

The first term represents the horizontal component of the acceleration of the pendulum mass, while the second similarly that of the rigid earth, *i. e.*, at T as well as at M. For a rigid earth the acceleration at M is the same as at T.

Taking the radius of the earth as unity, and putting $m = 1$, $r = 1$, then

$$f = g . \tag{2}$$

From the above figure we have

$$\sin z_1 = \frac{r}{r_1} \sin z ;$$

also $$r_1^2 = r^2 + 1 - 2 r \cos z = r^2 \left(1 - \frac{2 \cos z}{r} + \frac{1}{r^2}\right). \tag{3}$$

Hence from (1)

$$\xi = f \frac{m r \sin z}{r_1^3} - f \frac{m}{r^2} \sin z = f \frac{m \sin z}{r^2} \left(\frac{r^3}{r_1^3} - 1\right). \tag{4}$$

From (3) we have

$$\frac{r^2}{r_1^2} = \left[1 - \frac{2 \cos z}{r} + \frac{1}{r^2}\right]^{-1},$$

or $$\frac{r^3}{r_1^3} = \left[1 - \frac{2 \cos z}{r} + \frac{1}{r^2}\right]^{-\frac{3}{2}}.$$

Developing this expression and neglecting terms of the higher order, ($\frac{1}{r}$ being equal to about $\frac{1}{60}$), we have

$$\frac{r^3}{r_1^3} = 1 + \frac{3 \cos z}{r} .$$

Substituting this value in (4), then

$$\xi = f \frac{m \sin z}{r^3} 3 \cos z = \frac{3}{2} f \frac{m \sin 2 z}{r^3} . \tag{5}$$

If p denote the horizontal parallax of the moon, then

$$r = \frac{1}{\sin p} . \tag{6}$$

Substituting in (5) the values of f from (2), we have finally

$$\xi = \frac{3}{2} g m \sin^3 p \sin 2 z, \tag{7}$$

This formula was first given by Peters.

Applying this formula in our equation of $\epsilon = \frac{\xi}{g}$,

then $\epsilon = \frac{3}{2} m \sin^3 p \sin 2 z$, or in seconds of arc,

$$\epsilon'' = \frac{3}{2} \frac{m \sin^3 p}{\sin 1} \sin 2 z \tag{8}$$

From this last equation it is obvious that the maximum deflection ϵ''_m is at zenith distance 45°, that is, when $\sin 2z = 1$, in that case

$$\epsilon''_m = \frac{1}{2} \frac{m \sin p}{\sin 1''}. \qquad (9)$$

As $m = \frac{1}{81}$ mass of the earth, and in the mean $p = 57''$,

hence $\epsilon''_m = ''\cdot 017$, for the moon.

For the sun $m = 329000$, and $p = 8''\cdot 8$,

hence $\epsilon''_m = ''\cdot 008$, for the sun, or a little less than half that for the moon.

In the adjoining figure (Figure 3) P represents the terrestrial pole, Z_0, and Z the undisturbed and disturbed zeniths respec-

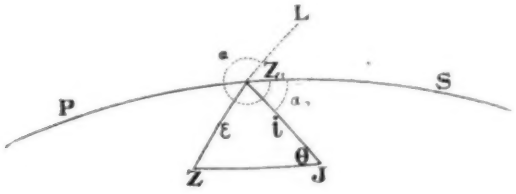


FIGURE 3

tively, which lie in the plane passing through the moon L, and J the rotation axis of the pendulum.

The deflection $Z_0 Z$ as before we designate by ϵ.

Counting the azimuth from the south through 360°, we have for the azimuth of the moon α and for the pendulum α_1; the position of the latter being defined by the plane passing through the axis of rotation and through the zenith, that is, the plane $Z_0 J$; and $Z_0 J = i$, the angle referred to already as determining the period of the pendulum.

In the undisturbed position, the centre of gravity of the pendulum lies in the plane $Z_0 J$, but in the disturbed (attracted) position in the plane $Z J$, so that the pendulum describes the arc or angle $Z_0 J Z$ or θ.

In the spherical triangle $Z_0 J Z$ we have

$$\frac{\sin \theta}{\sin (a - a_0 - 180°)} = \frac{\sin \epsilon}{\sin ZJ}$$

The angles ϵ and θ being very small we may put $ZJ = i$.

Writing the small angles themselves instead of their sines, we have

$$\theta = -\frac{\epsilon}{i} \sin (a - a_0). \tag{10}$$

The corresponding amplitude of the light-spot on the drum for which we had

$$y = 2A\theta$$

will be

$$y = -\frac{2A\epsilon \sin (a - a_0)}{i}. \tag{11}$$

Putting ϵ in seconds of arc, and $y = 1$ mm. then from (11) we have $\epsilon'' \sin (a - a_0) = -\dfrac{i}{2A \sin 1''}$;

or, expressing i in arc

$$\epsilon'' \sin (a - a_0) = -\frac{i''}{2A}. \tag{12}$$

Putting $(a - a_0) = 90°$, we obtain, irrespective of sign

$$\epsilon'' = \frac{i''}{2A}.$$

This magnitude is called the value of a millimetre on the drum, or the reduction constant.

Expressing ϵ and i in arc, equation (11) becomes

$$y = -\frac{2A\epsilon'' \sin (a - a_0)}{i''}. \tag{13}$$

We assume that two pendulums are mounted, the one in the meridian, $a_0 = 0°$; the other in the prime vertical, $a_0 = 90°$. The corresponding amplitudes or displacements of the respective light-spots on the drum we designate by y_M and y_V.

From equations (8) and (9) we have

$$\epsilon'' = \epsilon''_m \sin 2z.$$

Putting $\omega = -\frac{2A\epsilon''_m}{t^2}$, equation (13) becomes for the pendulum in the meridian, where $\alpha_o = 0°$,

$$y_M = \omega \sin \alpha \sin 2z, \tag{14}$$

and for the prime vertical $y_V = -\omega \cos \alpha \sin 2z$. (15)

We shall now express α and z in terms of the declination δ, and hour angle t of the moon.

The accompanying figure (Fig. 4) is a stereographic pro-

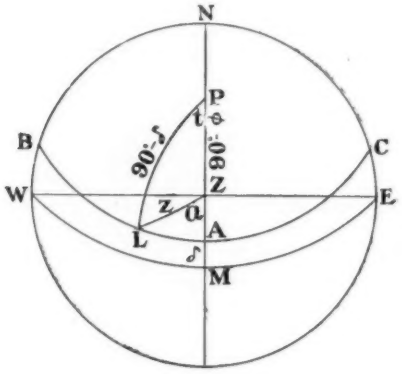


FIGURE 4

jection on the plane of the horizon of the observer. P is the pole, NZ the meridian, WME the celestial equator, BAC the declination circle passing through the moon L, $LPZ = t$ its hour angle, $LZM = \alpha$ its azimuth, $AM = \delta$ its declination, $LZ = z$ its zenith distance, $PL = 90° - \delta$ its co-declination, and $PZ = 90° - \phi$ the co-latitude of the observer or place of observation.

In the spherical triangle PLZ we have

$$\cos z = \sin \phi \sin \delta + \cos \phi \cos \delta \cos t \tag{16}$$

and $$\frac{\sin \alpha}{\sin t} = \frac{\cos \delta}{\sin z}, \text{ or } \sin \alpha \sin z = \cos \delta \sin t. \tag{17}$$

Furthermore in the general spherical triangle $A\,B\,C$ we have the fundamental formula

$$\sin a \cos C = \sin b \cos c - \cos b \sin c \cos A.$$

Substituting in it the corresponding values of our triangle $P\,L\,Z$, we have

$$\cos \alpha \sin z = - \sin \delta \cos \phi + \cos \delta \sin \phi \cos t. \qquad (18)$$

As formulæ (14), (15) contain $2z$, and remembering that $\sin 2z = 2 \sin z \cos z$, we get applying (16), (17), (18)

$$\begin{aligned} \sin \alpha \sin 2z &= 2 \sin \alpha \sin z \cos z \\ &= 2 \cos \delta \sin t \,(\sin \phi \sin \delta + \cos \phi \cos \delta \cos t) \\ &= \sin \phi \sin 2\delta \sin t + \cos \phi \cos^2 \delta \sin 2t. \end{aligned}$$

Again, $\cos \alpha \sin 2z = 2 \cos \alpha \sin z \cos z$; applying (16), (18) we have

$$\begin{aligned} \cos \alpha \sin 2z &= 2\,(-\cos \phi \sin \delta + \sin \phi \cos \delta \cos t) \\ &\qquad (\sin \phi \sin \delta + \cos \phi \cos \delta \cos t) \\ &= -\sin^2 \delta \sin 2\phi + (\sin^2 \phi \sin 2\delta - \cos^2 \phi \sin 2\delta) \cos t \\ &\qquad + \cos^2 \delta \sin 2\phi \cos^2 t. \end{aligned}$$

Applying

$\cos^2 t = \frac{1}{2}\,(1 + \cos 2t)$, and $\sin^2 \phi - \cos^2 \phi = -\cos 2\phi$,

we have

$$\begin{aligned} \cos \alpha \sin 2z = (&- \sin^2 \delta \sin 2\Phi + \tfrac{1}{2} \cos^2 \delta \sin 2\phi) \\ &- \sin 2\delta \cos 2\Phi \cos t + \tfrac{1}{2} \cos^2 \delta \sin 2\phi \cos 2t. \end{aligned}$$

Substituting the values found for $\sin \alpha \sin 2z$, and $\cos \alpha \sin 2z$ in (14), (15) we have

$$y_M = \omega \sin \Phi \sin 2\delta \sin t + \omega \cos \Phi \cos^2 \delta \sin 2t \qquad (19)$$

and $y_V = \omega \sin 2\Phi\,(\sin^2 \delta - \tfrac{1}{2} \cos^2 \delta) + \omega \cos 2\Phi \sin 2\delta \cos t$
$- \tfrac{1}{2}\,\omega \sin 2\Phi \cos^2 \delta \cos 2t. \qquad (20)$

In the last we may write for

$$\sin^2 \delta - \tfrac{1}{2} \cos^2 \delta = \tfrac{1}{2}\,(3 \sin^2 \delta - 1)$$

These are the expressions for the deflection or amplitude of the two light spots of the two pendulums on the drum.

In these last formulæ it will be observed that both y_M and y_V contain terms of the diurnal and semi-diurnal periods, *i. e.* of t and $2t$.

Their separation or evaluation is effected by means of harmonic analysis. The observations are first grouped according to solar time and for the same hour angle, and the mean of the respective ordinates is then taken. In a large number of observations for a given hour angle of the sun, the moon will have run through all possible hour angles, and hence the lunar terms will practically vanish and only those of the sun remain. Similarly we proceed in taking given hour angles of the moon and their mean ordinates. In this case the terms of the sun will disappear. It may be observed too that in a large number of observations, as far as a lunation is concerned the diurnal term vanishes, for in the terms of cos t and sin t we have sin 2δ, which in a lunation oscillates between the positive and negative signs. Hence by means of observations with horizontal pendulums we may determine the numerical value independent of the sign of the co-efficient ω, formula (13), and from it the constant ϵ_m.

For the moon, under the assumption of a perfectly rigid earth $\epsilon_m = ''017$. From the records of the horizontal pendulums the value derived for ϵ_m is about 2/3 of the theoretical value, *i. e.*, the amplitudes are not as large as would be the case with a perfectly rigid earth. It follows, therefore, that the earth has about the rigidity of steel, a conclusion arrived at by Kelvin years ago, and by quite another line of attack.

The observations furthermore show that the terms dependent upon the sun are largely influenced by meteorological conditions, amongst which the daily heating of the earth has already been referred to. Furthermore the change of declination must also be considered. For a small interval, say 24 hours, δ may be taken as proportional to t. We may express y_M in the form:

$$y_M = a + bt + B_1 \sin t + B_2 \sin 2t \qquad (21)$$

in which a, b, B_1 and B_2 are constants for small time intervals to be determined from the observations. Experience has shown

that a and b are quite large and dependent more on meteorological factors than on astronomical influences.

The sum of the non-periodic terms $a + bt$ in (21) determines the movement of the zero of the horizontal pendulum. It has been found desirable to mount the instruments in vaults at a sufficient depth beneath the surface so as to mitigate as much as possible the meteorological disturbances. The observations of Hecker, at Potsdam, were made at a depth of 25m. (82 ft.).

It was taken for granted that the magnitude of the deformation of the earth would show no selective azimuth, but observations showed this not to be the case. Taking the mean of the observations at Potsdam, Dorpat, Freiburg in B., and Durlach in B., we obtain ·47 for the meridian and ·70 for the prime-vertical value, of the theoretical value they should respectively have; which means that the earth is more compressible in a north-south than in an east-west direction. This anomaly was puzzling. Sir George Darwin suggested that the greater rigidity of the earth in the east-west direction was due to the rotation. Professor Love however, from mathematical considerations could not assign this as a reason. He however pointed out the possibility, as the difference was more marked at Potsdam, which is nearer to the ocean, than in Dorpat, that the ocean tides might be the disturbing factor, and in two ways. In the first place there must be a bending of the earth's crust under the tidal weight; and in the next place the tidal mass exercises its gravitational influence just as the moon and sun do. Acting on this suggestion the International Seismological Association at Manchester in 1911 decided to have four "deformation" stations established, one in central Siberia, one in central South Africa, one in central North America — these three being far removed from the ocean, — and one in Paris, where the above effects, if they exist, would be aggravated or increased. Canada undertook to establish the one for America, and Winnipeg was first selected, but it was finally decided that more satisfactory results would be obtained at Ottawa at the Dominion Observatory, under constant technical supervision. Recently a concrete

vault 9 × 21 ft. has been built adjoining the Observatory, the floor of the vault being 24 ft. below the surface, and the pendulums will shortly be installed.

Since the observations have been made in Europe, Professor Michelson has carried out a splendid series of observations, and by quite a new method, using two long (500 ft.) pipes, 6 inches in diameter, the one laid in the meridian, the other in the east-west line and both underground 6 ft. They are partially filled with water, and the change of level under lunar and solar attractions is measured by means of a microscope. A detailed account of the apparatus and results will be found in the March number of the *Astrophysical Journal* for the present year. We shall give his final results. He finds —

Amplitude	Ratio.	Phase	Acceleration.
N–S	·523	–	·007 hour
E–W	·710	+	·059 hour

We see that the amplitude ratio is in pretty good accordance with the mean European results of ·47 and ·70, and from the position of Michelson's station — Williams Bay, Wisconsin, near the Yerkes Observatory, very far away from any oceanic tidal influences the cause of the anomaly of this difference in amplitude ratio, will very likely have to be sought elsewhere — although Schweydar (1912) agrees with Love in attributing the difference as found at the European stations, to the effect of ocean tides. The phase acceleration as found by Michelson is very satisfactory, being very small as one would expect. It is as he says, "so small as to leave some doubt as to whether or not it is real."

We have shown in the preceding, the problem to be attacked and the method of attacking it. Attention has been drawn to the very small quantities involved, that is, the quantities to be measured, and of the numerous factors that enter into it, — the continuous change of the moon's position in declination and distance, with the consequent change in its tide-disturbing effect. The same applies, though in a less degree to the sun. To com-

plicate our record still more, we have meteorological effects impressed on the records, such as the heating effect by the sun. Yet from all the tangle, the physical tides of the earth show up clearly and unmistakably. At a maximum the surface of the earth rises and falls about a foot twice a day, due to lunar and solar attraction. We are sitting on a long 'teeter', (6000 miles long, with a period of a little over twelve hours), unconsciously teetering. It doesn't seem to mean much, yet in it is bound up the constitution of our earth, and of all objects in the universe none concerns man more than the earth. The earth is solid, very solid, somewhat like steel. There is no liquid molten interior as we were once led to believe.

We trust that in another year the Dominion Observatory will be able to add its share to this very interesting investigation of the deformation of the earth by the moon and sun, and the determination therefrom of the rigidity of the earth, a desirable quantity in geophysics.

DOMINION OBSERVATORY,
OTTAWA, CANADA,
September, 1914

HOW KNOWLEDGE GROWS — II

By J. C. Glashan

IN my former address I stated that the basis of all our knowledge of the outside world is sensory experience, that the impulse to knowledge arises from curiosity regarding experiences or interest in them, and that the growth of knowledge begins with the careful and critical testing, sifting and classifying of experiences. When through this classification and the comparisons and differentiations which it involves, we are led to discern or are enabled to discover the general beneath the particular, the permanent relation beneath the evanescent circumstance, knowledge becomes what in modern speech is named *Science*, *i. e.*, KNOWLEDGE *par excellence*. "When from many experiences there is formed one general conception which will embrace all similar cases, then understanding [Science] begins," so spoke Aristotle more than two milleniums ago. To sum up,— knowledge springs from an endeavor to answer the questions, *What?* *Where?* *When?* and *How?*. It culminates in science as a complete and intelligible description of the universe as known through sensory experience.

There is a fifth question, *Why?* that the vast majority of men have asked or do ask, but the attempted answers to this question have ever proved not helps but hindrances to the advance of knowledge, stumbling-blocks in the way. The animism of the savage persisting in many of the popular superstitions of the present day was man's first answer to the question *Why?*, and the doctrine of substantial forms and specific and occult qualities, the Delilah of the Peripatetic Schools, was but another attempt. Had Aristotle kept severely to descriptive natural history, to answering the questions, *What?* *Where?* *When?* in biology, the development of science, the growth of knowledge,

might have followed a different course from that which it actually took ; for, in his descriptions of the marine animals which he actually dissected, he proved himself a master of careful and minute observation, so much so, that he has won the unqualified praise of Darwin. But when he turns to physics, his lack of experience and disregard of experiment, conjoined with his ignorance of mathematics and contempt for mechanical explanations, led him to propound theories that were not only utterly baseless, but that led to absolute contradictions of actual occurrences in the external world.

It was, perhaps, re-action against this tendency to prescribe laws to the physical world, semi-personified as Nature, instead of seeking to learn through observation and experiment what are the laws followed, the sequences of events as they actually occur, in that world, that led Claudius Ptolemy again and again to declare in his *Mathematike Syntaxis*,— perhaps better known as *The Almagest*,— that his constructions were all purely mathematical, *i. e.*, geometrical, and not to be understood as in any way mechanical (physical) ; or in modern phrase, he offered his work as a purely analytical resolution of the actual motions into a set of circular motions, not as a physical exposition of the actual motions. Yet so strong is the attraction of the fatal *Why?*, that in defiance of Ptolemy's declarations and heedless of all warnings from the history of the decadence of Greek Philosophy, the astronomers of the Middle Ages and of the Renaissance, Arabian, Jewish and Christian all alike, sought to imagine and describe a mechanical construction, a vast machine, to account for the apparent motions of the planets and fixed stars. Even Copernicus, unwarned by Frascatore's 77 solid celestial spheres, proposed his system of 34 circles as a *physical* explanation of celestial phenomena, not merely as a kinematic analysis of them ; for, the famous preface to the *De Revolutionibus*, "*To the Reader, concerning the Hypotheses of this Work*" was written, not by Copernicus, but by Osiander. But although the celestial mechanics of Copernicus was physically false, *De Revolutionibus* was a magnificent example of independence of

thought, and as such it caused a veritable intellectual earthquake.

I said in my former address that science as a study and explanation of natural phenomena, suddenly arose among the ancient Greeks and was for a time sedulously cultivated, then interest in it waned until it became practically extinct for nearly a thousand years. There were several causes of this decline, all more or less contributory each in its own way. Perhaps the most noticeable and most potent of these is the tendency of men to build theories on insufficient and untrustworthy experiences, experiences carelessly observed, incorrectly recorded or imperfectly described, and uncritically accepted; and then, prepossessed with a prejudice, a fore-judgment, to reject, too often with anger, any new theory, and to refuse even to re-examine the evidence for the old one. This was the siren whose deceptive charms drew the Greek philosophers from the right path. They built a towering theory of the universe on a very slight and loose foundation of observed facts and their disciples spent themselves in raptures over these 'castles in Spain.' It was against these that Roger Cotes, in his *Preface* to the second edition of Newton's *Principia*, bitterly exclaimed,—"they .... run out into dreams and chimeras and neglect the true constitution of things, which certainly is not to be expected from fallacious conjectures, when we can scarcely reach it by the most certain observations. Those who fetch from hypotheses the foundations on which they build their speculations, may form indeed an ingenious romance, but a romance it still will be." It was against this tendency that Newton was protesting when he wrote "hypotheses non fingo," "I frame no hypotheses," which has recently been called a magnificent lie but which, as meant by Newton, was a magnificent truth; for he was speaking, not of hypotheses assumed for purposes of discovery, such as we shall later describe, but of hypotheses incapable of experimental verification put forward as substiutes for true physical explanations.*

*Newton was in fact speaking of hypotheses as to a physical cause of gravitation.

A second cause of the decline of science among the Greeks was the restriction of their mathematical and, as a consequence, of their mechanical knowledge. Sir John Herschel in his treatise on *Astronomy* has emphatically said:—"Admission to its sanctuary, and to the privileges and feelings of a votary is only to be gained by one means — *sound and sufficient knowledge of mathematics, the great instrument of all exact inquiry without which no man can ever make such advances in this or any other of the higher departments of science as can entitle him to form an independent opinion on any subject of discussion within their range.*" (The italics are the author's own). Greek mathematics was restricted in two ways. First, the Greek (and Roman) power of computation was hampered and numerical conceptions were narrowly limited by the Greek (Roman) system of numerical notation and that to an extent that is hard for us now to realize or understand.* The duplication of the cube was one of the three famous (*notorious* would be a better epithet) problems of antiquity, yet modern exponential notation reduces the proof of the impossibility of its solution by quadratic constructions to the simple statement that $\sqrt[3]{2}$ cannot be expressed as a terminating binary fraction. The modern form of the problem is De Morgan's "To fold a sheet of paper into three equal leaves without trial or measurement." As for the third of the famous problems of antiquity,—the rectification of the circle,—no Greek, not even Archimedes himself, could have grasped the significance of the statement,—'The ratio of the circumference of a circle to its diameter is a transcendental number,'—in modern mathematical parlance, 'π is not a root of an algebraic equation with rational co-efficients.'

*The Greek alphabetical and the Latin 'tally' systems of notation were 'systems for record' not 'systems for computation,' (*logistic* of the Greeks, *supputation* of the Romans). The specimens which have come down to us of computations in alphabetical notation are evidently merely samples of what was possible, not of what was practical. The calculations of the merchant were quickly and *easily* made on the abacus or the sand table, and then if necessary, recorded in alphabetical or in 'tally' notation.

The second restriction of Greek mathematics was the lack of a symbolism such as that employed in modern algebra and in the Infinitesimal Calculus. Greek mathematicians represented quantities and operations on them by geometrical figures and constructions. The Second Book of Euclid's Elements is the Greek equivalent of a chapter on quadratic equations in a modern work on elementary algebra. Now, in the hands of a master, geometrical construction is a magnificent instrument of demonstration, but for purposes of investigation it has ever proved a veritable bow of Ulysses. No one but Newton has ever been able to bend it to its full power. Even Archimedes failed to master it completely, for while he was able to solve by its use comparatively simple questions in statics, the solution of such problems as the motion of a spinning top, the flight through the air of a rapidly whirling ball, and the pressure of water flowing through a pipe of varying bore, was far in the future and was to be given by men of lesser genius employing the powerful instruments of modern analysis.

A third cause of the decline of science under the Roman Empire was the rise of Christianity with its proselytizing spirit and its consequent diversion of men's minds from the study of natural phenomena to discussions of spiritual affairs, from questions of *What?* and *How?* of matter, to questions of *Whence?* and *Whither?* of souls. Revelation was exalted over rational investigation and Biblical statement over observed fact. Even in the realm of nature, the question became, not whether this or that hypothesis accords with observed phenomena in the consequences which would necessarily follow from it if it were true, but whether it is in agreement with the expressed opinions of this or that ancient writer. Later, when the religious disputes of the Reformation had raised men's trust in Biblical interpretation to a veritable idolatry of the written word, the supersession

of reason by authority led to the Indexing* of *De Revolutionibus* and the condemnation of Galilei. It had even earlier led Luther to call Copernicus a 'fool' and Melancthon to declare of the Copernican system that wise rulers should coerce such unbridled licence of thought. To such men the witty apophthegm of Cardinal Baronius "In the Scriptures, the Holy Spirit intends to teach men how to go to Heaven, not how Heaven goes," would have been blasphemy, and they would undoubtedly have sent Laplace to the stake for his answer to the question 'In your *Mechanism of the Heavens*, where does God come in?' — 'I did not find it necessary to bring in God.'†

A fourth cause of the decline of scientific investigation was the subversion of the Western Roman Empire by the irruption of the Vandals, Goths and other Germanic races, themselves driven headlong before the still more barbaric Huns who poured into Europe through the gateway between the Ural Mountains and the Caspian Sea. Devastation and ruin reigned everywhere and for a time there seemed to be an end to all learning. When civilization again arose, the only learned men, the only teachers, the only leaders of thought, were churchmen, who naturally insisted on a literal interpretation of every syllable of the Hebrew and Christian Scriptures, books written by men who

*By a decree of the Congregation of the Index, dated 5th March 1616, the book *De Revolutionibus* was suspended (it was never condemned and prohibited) until corrected, as teaching 'Falsam illam doctrinam Pythagoricam, divinæ que Scripturæ omnino adversantem, de mobilitate Terræ et immobilitate Solis.' In the year 1620 under an undated 'Monitum ad Nicolai Copernici lectorem' appeared a list of corrections subject to which the book of Copernicus might be reprinted and read. The corrections relate 'locis in quibus non ex hypothesi, sed asserendo de situ et motu Terræ disputat.'

† Both question and answer had reference to Voltaire's declaration that the only possible explanation of gravitation (then accepted as action at a distance across empty space) was the continual exertion of the will of God, and that therefore no man could explain the mechanism of the heavens by the Newtonian philosophy, of which Voltaire was an ardent and able advocate, without postulating the existence of God. To Voltaire, Newton's *Principia* was a mathematical refutation of atheism.

naively recounted Sumerian myths and Accadian legends as historical facts, and whose views of natural phenomena were the same as those of the roving Bedaween. But their insistence on acceptance of ancient beliefs differed from the dogmatic teaching of the Christain Fathers in that the latter arose from a passionate desire for and interest in the salvation of men's souls, while the former sprang from the root-instinct which produces pack-loyalty in the brute, horde-loyalty in the savage, race-loyalty in the civilized man, and belief-loyalty, often degenerating to intellectual slavery, in the disciple ; the instinct which, in perverted form, leads so many otherwise sensible men to prefer 'old wives' fables' to the evidence of their own senses. If it was true in Dryden's day that,

> "The priest continues what the nurse began,
> And thus the child imposes on the man."

it was not because the priest was known to be good but because he was believed to be learned.

To sum the whole in a single sentence ; — The prejudices of uncritical 'common sense', the imperfection and limitation of mathematical methods, the diversion of intellectual interest to theology and consequent exaltation of revelation over observation, and lastly the recrudescence of the animistic superstitions of barbarians, were the main causes of the brumal fogs and the intellectual hibernation of the 'dark ages'.

But when the time was ripe, there appeared the all-gifted Leonardo da Vinci and the single-minded Copernicus, twin heralds of a glorious vernal awakening which the equinoctial storms of the Reformation and the Wars of Religion might temporarily retard but could not permanently stay. Da Vinci died on the 2nd of May 1519 and Copernicus on the 24th of May 1543, and within the next thirty years were born three men, Francis Bacon in January 1561, Galileo Galilei in April 1564, and John Kepler in December 1571, who were destined, each in his own way, to revolutionize men's views of science and methods of scientific research. A year after the death of Galilei and five months

less than a century after the death of Copernicus, on Christmas Day 1542, O. S., (4th January 1543, N. S.,) Sir Isaac Newton was born, the greatest mathematician and physical investigator the world has yet seen. Of him Pope truly said

> "Nature and Nature's laws lay hid in night,
> God said 'Let Newton be!' and all was light."

Let me briefly state what each of these men did towards establishing what is now recognized as the proper method of scientific research, for we can learn how knowledge grows only by studying how it has grown.

From shortly after the days of Newton until the middle of the nineteenth century, it was believed, at least in England, that Francis Bacon was the great protagonist of the Aristotelian schools and the reformer of methods of scientific investigation. The value of Bacon's purely inductive method is now very variously estimated by different critics, but there can be no question of the influence of his philosophy in over-throwing the dominance of authority both Aristotelian and vulgarian. The very first aphorism of his *Novum Organum* is, — "Man being the servant and interpreter of nature can do and understand so much, and so much only, as he has observed in fact or in thought, of the course of nature; beyond this he neither knows anything nor can do anything."

The method Bacon proposed was the collection of facts as resultant from observation and experiment, the criticism, analysis and classification of these facts and finally the formulation of the truths, the laws of nature, thus rendered perceptible. It may fairly be questioned whether any scientific discovery worthy of the name was ever made by following this method and we may well say with De Morgan, "Great as Bacon was and great as his *Novum Organum* really is, he was not the philosophical father of modern discovery." But in justice, we must also add from Whewell, — "What Bacon really did was this; — by the august image which he presented of a future Philosophy, the rival of the Aristotelian, and far more powerful and extensive,

he drew to it the affections and hopes of all men of comprehensive and vigorous minds, as well as of those who attended to special trains of discovery. He announced a New Method, not merely a correction of special current errors; he thus converted the Insurrection into a Revolution, and established a new philosophical Dynasty." And Thomas Fowler in his brief examination of Bacon's philosophy holds that the real lessons taught in it are, — "The duty of taking nothing upon trust which we can verify for ourselves; of rigidly examining our first principles; of being carefully on our guard against the various delusions arising from the peculiarities of human nature, from our various interests and pursuits, from the force of words, and from the disputes and traditions of the different schools of thought; the duty of forming our conclusions slowly and of constantly checking them by comparison with facts; of avoiding merely subtle and frivolous disputations; of confining our inquiries to questions of which the solution is within our power; and of subordinating all our investigations to the welfare of man and society."

While Bacon was announcing a New Engine of scientific investigation, Kepler and Galilei were practising a new method. This new method has been so excellently described by De Morgan that I cannot do better than quote his words. "A few facts have suggested an *hypothesis*, which means a *supposition*, proper to explain them. The necessary results of this supposition are worked out, and then, and not till then, other facts are examined to see if these ulterior results are found in nature. The trial of the hypothesis is the *special object:* prior to which, hypothesis must have been started, not by rule, but by that sagacity of which no description can be given, precisely because the very owners of it do not act under laws perceptible to themselves. The inventor of hypothesis, if pressed to explain his method, must answer as did Zerah Colburn, when asked for his mode of instantaneous calculation. When the poor boy had been bothered for sometime in this manner, he cried out in a huff, 'God put it into my head, and I can't put it into yours.'"

Of the character and value of Kepler's labors here is Berry's

summing up and estimate: "There are few astronomers about whose merits such different opinions have been held as about Kepler's. There is, it is true, a general agreement as to the great importance of his three laws of planetary motion, and as to the substantial value of the *Rudolphine Tables* and various minor discoveries. These results, however, fill but a small part of Kepler's voluminous writings, which are encumbered with masses of wild speculation, of mystic and occult fancies, of astrology, weather prophecies, and the like which are not only worthless from the standpoint of modern astronomy, but which — unlike many erroneous or imperfect speculations — in no way pointed towards the direction in which the science was next to make progress, and must have appeared almost as unsound to sober-minded contemporaries like Galilei as to us. Hence, as one reads chapter after chapter without a lucid, still less a correct, idea, it is impossible to refrain from regrets that the intelligence of Kepler should have been so wasted, and it is difficult not to suspect at times that some of the valuable results which lie imbedded in this great mass of tedious speculation were arrived at by mere accident. On the other hand, it must not be forgotten that such accidents have a habit of happening only to great men, and that if Kepler loved to give reins to his imagination he was equally impressed with the necessity of scrupulously comparing speculative results with observed facts, and of surrendering without demur the most beloved of his fancies if it was unable to stand this test. If Kepler had burned three-quarters of what he printed, we should in all probability have formed a higher opinion of his intellectual grasp and sobriety of judgment, but we should have lost to a great extent the impression of extraordinary enthusiasm and industry, and of almost unequaled intellectual honesty, which we now get from a study of his works."

This in some parts is a severe judgment, in fact severe to injustice. Let us remember what Faraday, the greatest master of physical research since the days of Newton, once said, — "The world little knows how many of the thoughts and theories which

have passed through the mind of a scientific investigator have been crushed in silence and secrecy by his own severe criticism and adverse examination ; that in the most successful instances not a tenth of the suggestions, the hopes, the wishes, the preliminary conclusions have been verified" : and again he said, — "Show me the scientific man who has made no mistakes and I will show you a man who has made no discoveries."

It may be true that astronomy would have lost nothing if ten of the eleven volumes of Kepler's collected works had never been published, but humanity as well as the science of mind would have been poorer for the suppression. And in its preliminary stage what more fanciful speculation in the eyes of his contemporaries could Kepler have proposed than was that which resulted in the establishment of his three laws of planetary motion. As to the effect of that establishment on the science of his day, it is perhaps beyond our full comprehension. With the exception of Galilei, no man then living could explain how, if the earth rotated on its axis and revolved about the sun, an arrow shot vertically upwards could possibly fall back upon the spot whence it was sped. The dynamics of that day taught that if a ball were dropped from the top of the mast of a ship borne smoothly and steadily forward by a swift current, it would fall on the deck, not at the foot of the mast, but far behind it. So sure were all men of the truth of this, that nobody thought of testing it by experiment, they would even have laughed at any proposal to do so. (On one occasion the writer, then a boy, was called 'a fool' because he said that the ball would fall on the same spot on the deck whether the ship lay at anchor or moved forward *steadily*.) It was in an attempt to secure Copernican simplicity and at the same time to satisfy the Aristotelian mechanics that Tycho Brahe proposed his strange hybrid system of the universe. But with the firm establishment of Kepler's Laws, not only were the whole Ptolemaic system and all the thirty-four eccentrics and epicycles of Copernicus swept into the discard, not only was Brahe's system made to look like a freak of the imagination, the whole edifice of Aristotelian mechanics

was tumbled from its foundations and the foundations themselves were torn up. A Galilei was made absolutely necessary.

Of Galileo Galilei's scientific discoveries I do not here speak, it is with his method of research I am here concerned. This method he did not announce as a *Novum Organum*, a New Instrument; he did better, he taught it by example. One such example must here suffice: — Galilei had challenged the truth of the Aristotelian doctrine, that heavy bodies fall faster than light bodies of the same material and had proved it to be false by dropping weights from the top of the leaning tower of Pisa. During the course of this experiment he noticed that the farther the weights fell the faster they went. Here was a new question; — What is the rate of this acceleration, this quickening of speed? In the then state of mechanical science this question could not be answered by direct experiment, so Galilei had recourse to hypothesis, deduction therefrom, and test of the agreement of the conclusions of deduction with the results of experiment. Two hypotheses occurred to him: 1st, that the speed of falling was proportional to the distance fallen; 2nd, that the speed of falling was proportional to the time during which the body had been falling. By a slip in reasoning he was led to reject the first hypothesis. From the second he deduced that the entire distance fallen during any time measured from the beginning of the fall would be proportional to the square of the time of falling. But bodies falling freely moved too fast to be dealt with by the crude apparatus of those days, so Galilei had recourse to experiments with weights sliding down inclined planes, and he found that the results of his experiments verified the sufficiency of his assumption and by deductive reasoning it could be proved that no other assumption would give the same results; thus was established its truth. It remained to deal with the speed of a body falling freely, and this he did as follows. By experiment he found that a body sliding down one very smooth inclined plane acquired speed enough to carry it up another smooth plane to its original height, however, different from each other the slopes of the two planes might be. It followed as an immediate consequence that

it was the height alone which mattered and therefore that a body falling freely and a body sliding down a perfectly smooth inclined plane would acquire the same speed provided the total heights descended were the same. Hence, the law of acceleration established for the sliding body was also true of the body falling freely.

It may be of interest to add that the experiments with weights sliding down inclined planes led to the establishment and enunciation of the First Law of Motion, a law which flatly contradicted all previous theories and opinions.

In the study of dynamics (kinetics) Galilei had no predecessors, for the work of Da Vinci seems to have been unknown to him as to his contemporaries, he inherited nothing but erroneous traditions and obscure ideas, yet he was able to lay a broad and secure foundation for the mighty structure which later mathematicians have reared upon it. As to his method of investigation it sprang full grown from his mind even as Athene is fabled to have sprung full-armed from the head of Zeus. Was it not a strange coincidence that Galilei and Shakespeare were born in the same year, within three months of each other; Galilei the master revealer of the laws of inanimate nature; Shakespeare the master limner of the course of human passion!

[Part of the lecture is here omitted;] it contained,—

(*a*) A description of the method of investigation employed by Newton who nowhere so much as mentions Bacon or the *Novum Organum*.

(*b*) A description of the method adopted by Darwin who declared himself a disciple of Bacon.

(*c*) A detailed description of the method followed by Pasteur in the investigations which led to his discovery of the hemihedral forms of the crystals of the dextro—and the lævo-tartarates of soda and ammonia, a method summed up by Mitscherlich in the words,—So you are the young man who has solved the problem which had baffled me for twenty years; but you were able to do so because you started with an hypothesis which I did not possess.

But what is the final purpose, what the end of all this search after, this gathering up of knowledge? Is it merely that we may make our physical life easier and longer, that we may win the reward promised of old by Empedocles,—

"And thou shalt master every drug that e'er
Was made defence 'gainst sickness and old age —
And thou shalt calm the might of tireless winds
That burst on earth and ruin seedlands; aye,
And if thou wilt, shalt thou arouse the blasts
And watch them take their vengeance, wild and shrill,
For that before thou cowedst them. Thou shalt change
Black rain to drought, at seasons good for men,
And the long drought of summer shalt thou change
To torrents, nourishing the mountain trees
As down they stream from ether."

Is it that we may at the last discover that

"Beyond the bright search lights of science,
Out of sight of the windows of sense,
Old riddles still bid us defiance,
Old questions of *Why* and of *Whence*.
There, fail all sure means of trial,
There, end all the pathways we've trod
Where man, by belief or denial,
Is weaving the purpose of God."

Or do we labor only at the end to learn the mocking lesson,

"Man weaves, and is clothed with derision,
Sows, and he shall not reap;
His life is a watch and a vision
Between a sleep and a sleep."

Not so. The garnering of knowledge is for the winning of wisdom, for wisdom is but knowledge in action, and wisdom, labor, love, constitute the complete life. The final purpose of all our labors, all our researches is then, not merely to make men do right things, but to enjoy right things; not merely to be industrious, but to love industry; not merely to be learned, but to love knowledge; not merely to be pure, but to love purity; not merely to search for truth, but when truth is found to guard it as more precious than rubies, for the gain thereof is better than the gain of fine gold, and none of the things man's heart can desire is to be compared to it.

OTTAWA, CANADA.

MEETINGS OF THE SOCIETY

At Toronto

October 6, 1914.—The first regular meeting of the autumn term was held this evening in the Society's rooms, 198 College St. Mr. H. B. Collier was in the chair.

The Librarian reported the receipt of a large number of Publications and Exchanges during the summer months, and the purchase of several new astronomical books which are now on the library shelves.

The evening was devoted to the discussion of observations made during the summer. Especial reference was made to Delavan's Comet, known as 1913*f*. To assist further observing of it, the comet's path for a considerable time was shown on the blackboard. Reference was also made to the comets known as Campbell's, Newbegin's and Encke's.

In answer to a query, Professor Chant stated that the reason why at the equinoxes, the day-time is longer than the night-time, as calculated from tables giving the times of sunrise and sunset for each day of the year, is to be found in the fact that in calculating the time of sunrise or of sunset allowance is made for the semi-diameter of the sun and also for atmospheric refraction.

October 20. — The following were elected members of the Society.

Arthur E. Rosborough, B.A., Calgary, Alberta.

O. V. Jewitt, B.A., Chatham, Ontario.

Frank W. Booth, 19½ Tranby Ave., Toronto.

The lecture of the evening was given by Dr. A. A. Hibner, of Hamilton, on "Astrology and the Astronomical Yardstick." A number of slides of astronomical bodies were first shown to place before the audience phenomena to which reference was later made in the lecture. A review of the origin of astrology was given, and of references in the Bible and writings of prominent men in the life of the world. An account of astronomical problems was also given to show their magnitude and significance, and theories in connection with these problems were outlined.

The lecture was discussed by several members.

November 3. — Mr. J. R. Collins reported some interesting observations which he had made on the comets in the sky.

Dr. C. A. Chant gave the lecture of the evening on "The Transits of Venus and Mercury." Special attention was given to the transit of Mercury to take place on Saturday morning, November 7, 1914.

Dr. Chant first gave a description of the motion of the planets about the sun and showed how to calculate the times of conjunction of the earth and Mercury. The positions of the earth, Mercury and the sun at possible conjunctions were illustrated by a model and the meaning of the various terms which are used was demonstrated. A table of the times of conjunctions for this century was given.

The transits of Venus were similarly considered and illustrated by means of slides.

November 17. — Mr. S. Dillon Mills occupied the chair.

A letter from the Secretary of the Smithsonian Institution, Washington, addressed to the Treasurer was read, requesting permission to reprint in their publications the address of the retiring president of last year, Professor L. B. Stewart, as it appeared in the Society's JOURNAL for January-February of

this year, on "The Form and Constitution of the Earth." This signal honor shown to Professor Stewart was favorably commented on by several of the members.

The ephemeris of Campbell's Comet up to March of next year was read as received from Harvard College Observatory.

Reference was made to the transit of Mercury across the face of the sun on the morning of November the 7th, but it was reported that owing to the cloudiness of the region of the sky surrounding the rising sun, the phenomenon was observed from Toronto for a few seconds only.

The paper for the evening was by Mr. J. Patterson, M.A., of the Meteorological Observatory, on "A Meteorological Trip to the Arctic Circle."

Mr. Patterson gave a very interesting and vivid description of a trip to the Arctic Circle, from which he had but recently returned. The meteorological data which he had secured will not be available for discussion for some considerable time. The lecture was profusely illustrated by lantern slides showing the manner and method of travel, the nature and resources of the part of the country through which he passed and his experiences with some of the natives.

L. G.

At Hamilton

November 19, 1914. — The first meeting of the fall session of of the Hamilton Centre was held this evening when the Local President, Mr. Wm. Bruce, gave the second section of his lecture on "Wonders of the Heavens."

He described the following constellations, Canis Minor, Monoceros, Orion, Taurus, Aries, Pisces, Delphinus and Aquila.

A pleasing feature was the use of large and artistic sketches of the constellations, made by the lecturer, in place of lantern slides.

T. H. W.

AT GUELPH

December 2, 1914 — Members and friends of the Society at this Centre had a very enjoyable meeting on the evening of Wednesday, December 2nd. The meeting was addressed by the President of the Society, Dr. J. S. Plaskett, of Ottawa, on the subject of "Canada's New Telescope at Victoria B. C., and its Uses." The lecture was exceedingly interesting and instructive. Every Centre in Canada should get Dr. Plaskett for that lecture. The members of the R.A.S.C. cannot afford to miss it. They should know what he can tell them about Canada's New Telescope.

Officers for the year 1915 were elected as follows:—

Honorary-President — Mr. H. Westoby.

Honorary Vice-President — Mr. Jas. Davison, B.A.

President—Professor W. H. Day, M.A.

1st Vice-President—Dr. H. G. Roberts.

2nd Vice-President—Mr. H. G. B. Leadley.

Secretary-Treasurer—Mr. R. R. Graham, B.A.

Recorder—Mr. J. T. Luton, M.A.

Council—Mrs. J. J. Drew, Miss M. Mills, Messrs. McNiece, Luton, Graesser, Asbury, Col. D. McCrae, and Ald. H. Mahoney.

J. T. L.

NOTES FROM THE DOMINION OBSERVATORY

THE NEW GEODETIC BUILDING

The new building for housing the staff of the Geodetic and International Boundary Surveys has been completed and is now occupied by these two divisions of the Astronomical Branch of the Interior Department. The building is of red brick with red sandstone trimmings, contains three stories and basement and is well adapted for its purpose. It is situated about 200 feet northwest of the main observatory building, and this grouping together of the whole staff of the Chief Astronomer much simplifies the administration and management.

The completion of this building has relieved some of the congestion in the observatory building and has given more room to the meridian and astrophysical divisions, thus enabling the work to be carried on to much greater advantage.

THE 72-INCH REFLECTING TELESCOPE

Good progress is being made with the construction of the mounting of the telescope. The heavy steel castings and forgings for axes, tube, and bearings of the telescope are being made for the Warner and Swasey Co. by the firms in Cleveland and Pittsburgh best adapted for this work. These parts will be completed early in the new year, when the shop erection of the mounting will begin. The parts of the driving clock, the slow motions and all other operating details are now being constructed by the Warner and Swasey Co. It is confidently expected that the mounting will be completed by October next.

Excellent progress is also being made on the great disc for the main mirror. The photograph with Dr. Brashear beside it (Plate XIII.) gives a good idea of the size of the glass casting. As stated in the last issue of the JOURNAL, it measured 73⅝ inches in diameter, 13⅝ inches in thickness and weighed 4962 pounds. Dr. Brashear informs me that the disc started from Antwerp about a week before the war broke out, and in due time it landed in New York. The Pennsylvania Railroad was about a week finding a suitable car to transport it to Pittsburgh, as the package was an enormous one, the crate adding 1200 pounds to the weight. Then it was some time before an iron wagon could be got to take it to the workshop, and on arriving there the six-foot doorway had to be removed to admit the disc, stripped of its packing-case. But at last it was safely placed on the grinding table which had been prepared for it.

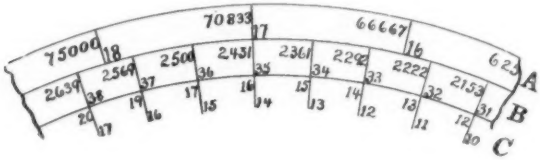
Then the first operation was to grind off the edge, and in doing so about half a cubic foot was removed. The grinding was done with a 30-inch steel circular saw, rotated so as to touch on the side of the saw near the edge, coarse emery mixed with crushed steel being supplied to it. The steel cuts about three times as fast as the emery. After about three weeks' labor the edge was successfully trued up and preparations were made for grinding out the central hole which was just six inches in diameter on the upper side, tapering irregularly. Flexible cutters were used at first so as not to endanger the disc by undue pressure. The cutter was shaped somewhat like a letter S, and was rotated about an axis through its middle, and the wings being so curved they readily yielded to any extra pressure coming upon them. In this way the hole was bored out to nine inches in diameter, when cast-iron cylindrical cutters were put in place of the sheet steel cutters and in a short time the hole was enlarged to over ten inches. Its edge was then smoothed up and made exactly square with the surface, and after that the top edge of the hole was bevelled off. This work of enlarging and smoothing off the central hole was the most dangerous part of the operations and happily it was done with complete success.

The upper and lower surfaces will next be made plane, and then that surface which seems the best will be ground into its parabolic form. The more the disc is examined the better it seems to be, and hopes are high that it will prove a great success.

J. S. P.

A DEVICE FOR CONVERTING HOURS, MINUTES AND SECONDS INTO FRACTIONS OF A DAY, AND VICE VERSA

The task of performing the above mentioned operations becomes laborious to a degree, directly proportional to the number of times it has to be done. The accompanying figure repre-



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sents a device used by the writer for some time. It consists of three card-board circles pivoted about the centre O, The circle A, which is the largest, has its circumference divided into twenty-four equal parts and in the bottom left corner of each division are written consecutively the numbers from one to twenty-four, and just to the left and above each number is written the fraction of a day, correct to five decimals, which that number of hours represents. The circle B, which is a little smaller than A, is divided into sixty equal parts, and gives the minutes and the fractions of a day corresponding; while the circle C gives the same for the seconds.

The operation of the instrument is very simple. If, for instance, we require to know what fraction of a day 17 hours, 35 minutes, 14 seconds represents, we turn the circles till the numbers 17, 35, 14 are in line, (see figure) and mentally add the numbers to the left of the line, beginning at the left digit. In use it is convenient to have the numbers for the hours, minutes and seconds in ink of one color and the decimals of a day in another. Small handles attached to the circles make it more convenient to operate. Two circles placed behind A bearing a suitable arrangement of numbers will perform the reverse operation. Circles eight inches in diameter will give ample room for writing in the required number of digits.

REYNOLD K. YOUNG.

NOTES FROM THE METEOROLOGICAL SERVICE

Summary Report of the Weather in Canada

October

Temperature.—In Manitoba and over the larger part of Ontario the past month was one of the warmest Octobers on record, and over practically the whole Dominion the mean temperature was higher than the average. The most pronounced positive departures from average occurred in Southeastern Manitoba, amounting to 9°, while over the remainder of that Province, and also in Southern Saskatchewan and Southern Ontario, the excess of the average was nowhere less than 3°.

Precipitation.—The precipitation was quite generally in excess of the average over the Western Provinces, in strong contrast to October, 1913, where there was a marked deficiency. In British Columbia the rainfall was well up to the average except in the Interior, and in Eastern Quebec and Northern New Brunswick exceeded it, but in Ontario, Southern New Brunswick and Nova Scotia there was quite a pronounced deficiency.

November

Temperature.—The temperature was above the average over the greater portion of British Columbia, throughout the Western Provinces, also in Ontario over the western half of the Lake Superior District and in the southern portion of the Peninsula, elsewhere in the Dominion it was below the average. The

largest positive departures occurred in the Western Provinces, Medicine Hat recording an excess of as much as 10°, with Battleford and Calgary 7° and 6° respectively ; from the eastern half of the Lake Superior District, in all parts of Quebec, and in northern New Bruswick, the negative departure varied between 3° and 5°.

Precipitation. — Near the coast and in the extreme north of British Columbia the precipitation was in excess of the average, and in the higher districts much fell as snow ; elsewhere in the Province it was about normal. In the Western Provinces, where as usual in November there was little, if any, rain, the snowfall was nearly average. In Ontario in some districts, especially in Muskoka and the Ottawa Valley, the precipitation was heavy, but it was in most parts nearly average. In Quebec the fall over the major portion of the Province was from three-quarters of an inch to nearly two inches more than the normal quantity, while in the Maritime Provinces it was everywhere very deficient, the negative departure being in nearly all localities from one-and-a-half to two-and-a-half inches.

Temperatures for October and November, 1914

Station	October		November	
	Highest	Lowest	Highest	Lowest
Yukon				
Dawson	54	12	36	20
British Columbia				
Atlin	49	24	42	0
Agassiz	71	34	52	28
Barkerville	60	22	46	2
Kamloops	68	29	56	16
New Westminster	70	40	56	28
Prince Rupert	66	38	52	26
Vancouver	67	38	56	30
Victoria	67	42	54	28
Western Provinces				
Battleford	75	24	55	15
Broadview				
Calgary	76	22	58	-10
Carman				
Edmonton	67	23	55	- 6
Medicine Hat	78	28	62	0
Minnedosa	82	20	60	-22
Moose Jaw	80	14	63	-17
Oakbank	84	17	52	-20
Portage la Prairie	84	18	62	-19
Prince Albert	64	16	44	-12
Qu'Appelle	77	9	57	-21
Regina	77	9	57	-20
Swift Current	80	28	64	- 2
Winnipeg	84	16	54	-14
Ontario				
Agincourt	78	23	61	9
Aurora	76	23	61	8
Bancroft	75	15	61	- 9
Barrie	76	23	61	6
Beatrice	72	25	60	0
Birnam	76	25	65	11
Bloomfield	73	21	60	10
Brantford	80	20	64	7
Bruce Mines				
Chatham	82	24	70	14
Clinton	77	23	60	- 5
Cottam	80	18	74	5
Gravenhurst	77	22	62	0
Guelph	76	20	61	7
Haliburton	78	15	62	- 7
Hamilton	76	25		
Huntsville	78	17	60	- 2
Kenora			51	-12
Kinmount	75	18	60	11
Kingston	72	22	58	10
Lakefield	75	25		
London	80	22	63	5
Lucknow	78	22	59	4
Madoc				
Midland	78	40	64	27
North Gower	80	12	60	-10
Otonabee				
Ottawa	76	23	65	0
Owen Sound				
Paris	77	22	64	3
Parry Sound	74	18	60	0
Peterboro'	77	19	60	5
Port Arthur	68	20	50	- 0
Port Burwell	71	20	61	12
Port Dover	75	20	64	12
Port Stanley	70	23	65	13
Ronville	76	12	59	0
Sarnia				
Southampton	74	25	58	15
Stonecliffe	78	20	60	- 4
Stony Creek	78	24	65	12
Stratford				
Toronto	79	26	62	13
Uxbridge	77	22	60	4
Wallaceburg	79	24	65	12
Welland	69	27	59	16
White River	74	2	46	-24
Quebec				
Brome	73	22	61	5
Father Point	56	26	44	0
Montreal	71	24	62	3
Quebec	68	23	50	2
Sherbrooke	74	23	63	5
Maritime Provinces				
Charlottetown	68	28	52	12
Chatham	78	18	56	2
Dalhousie	74	21	44	0
Fredericton	77	13	58	3
Halifax	70	22	62	8
Moncton	74	18	58	3
St. John	74	24	57	10
St. Stephen	78	13	59	8
Sussex	74	18	61	4
Sydney	69	30	60	20
Yarmouth	67	30	58	15

MAGNETIC OBSERVATIONS

During the month of October the magnetic field of the earth was more or less disturbed as shown by photographic traces of the magnetic elements at Agincourt. The only disturbances of magnitude, however, occurred on the 28th and 29th and these were marked by the rapidity of change of Force and Declination and the magnitude of the changes. At $23^h\ 18^m$ on the 28th the W. Declination suddenly diminished by 27′ followed by a rise in the next 4 minutes of time of 34′. At the same time the Horizontal Force increased 259γ and then diminished 273γ whilst the Vertical Force increased 114γ followed by a diminution of 219γ.

During November, except from the 20th to the 25th inclusive, the forces were generally slightly disturbed.

Declination W.

Month	Mean of Month	Max.	Date	Min.	Date	Monthly Range	Amplitudes—Mean Daily	
							From hourly readings	From Means of Extremes
1914	° ′	° ′		° ′		° ′	′	′
Oct.	6 26·0	6 39·7	16	5 49·8	28	0 49·9	6·2	15·5
Nov.	6 26·4	6 45·7	11	6 11·5	18	0 34·2	5·3	12·1

Horizontal Force.—C.G.S. Units

1914								
Oct.	0·16055	0·16204	28	0·15879	29	0·00325	0·00024	0·00057
Nov.	0·16053	0·16086	10	0·15956	4	0·00130	0·00023	0·00045

Vertical Force.—C.G.S. Units.

1914								
Oct.	0·58594	0·58782	28	0·58519	28	0·00263	0·00015	
Nov.	0·58594	0·58715	4	0·58530	4	0·00085	0.00005	0·00019

Inclination

Month	Mean Earth Inductor
	° ′
1914	
October	74 42·2
November	74 42·6

Earthquake Records by the Milne Seismograph

TORONTO

R F Stupart, Director

P. T. = Preliminary Tremors. L.W. = Large Waves. A.C. = Air Currents.
Time is Greenwich Civil Mean Time, 0 or 24 h = midnight.

No.	Date 1914		P. T. Comm.	L.W. Comm.	Max.	End	Max. Amp.	Durat.	Remarks
			h m	h m	h m	h m	mm	h m	
1389	Oct.	1	6 26·8	6 40·0	6 52·8	7 13·7	0·2	0 46·9	
1390	"	3	17 30·3	17 35·8	17 41·0 17 43·1	19 41·2	2·0 2·7	2 10·9	Paper changed at 17h 48m·5. Earthquake at Martinique.
1391	"	3	22 29·6?	S22 33·1 L 2 47·1	22 59·1	24 0·0	0·9	1 30·4	Asia Minor.
1392	"	8	12 30 7?	12 52·1		13 8·1	0·05	0 37·4	
1393	"	9		3 46·0		3 55·6	0·1	0 9·6	
1394	"	14	14 24·2	14 27·7		A. C.	0·05		
1395	"	14	19 38·4?	19 41·9		19 45·2	0·2	0 6·8	Doubtful as to being seismic.
1396	"	17	7 3·9	7 5·8		7 25·0	0·2	0 21·1	
1397	"	21	16 19·2	16 33·8		16 43·4	0·05	0 24·2	
1398	"	22	6 59·5			7 2·3	0·2	0 2·8	
1399	"	22		16 38·0		16 45·2	0·2	0 7·2	
1400	"	23	6 40·4	6 51·1		A. C.	0·2		A. C. after 7h.
1401	"	25	19 33·8	19 38 8		A. C.	0·1		A. C. going on.
1402	"	27	4 9·4			4 56·8	0·3	0 47·4	Sudden beginning.
1403	"	27	16 26·2?	16 30·5		16 55·4	0·05	0 29·2	
1404	"	28		0 42·0 0 51·1		1 41·7	0·05	1 2·7	
1405	Nov.	7		7 30·3		8 18·3	0·1	0 48·0	
1406	"	8		7 27·5		7 39·8	0·2	0 12·3	
1407	"	8	8 0·2?	8 5·2		8 13·6	0·2	0 13·4	
1408	"	8	20 47·1?	20 52·2		A. C.	0·05		
1409	"	10	7 16·8	7 32·8 7 38·3	7 40·5	7 50·3	0·3	0 3 ·5	L.W. well-defined.
1410	"	10	11 16·8	11 29·5		A. C.	0·1		A. C. going on.
1411	"	18	9 48·3	9 58·8	10 1·2	11 31·3	0·8	1 43·0	Marked disturbances.
1412	"	22	8 48·0	9 0·2	9 20·7	9 54·4	0·2	1 6·4	
1413	"	24	8 6·1	8 16·6		8 54·0	0·1	0 47·9	
1414	"	24	12 4·1 12 9·3	12 20·4	12 26·6 12 47·9	15 4·0?	1·4 1·5	2 59·9	Appears like a double earthquake.
1415	"	27	15 15·2?	15 23·8		15 27·9	0·05	0 12 7	Ionian Islands.
1416	"	28	11 28·6	11 50·9	11 57·4	12 27·6?	0·3	0 59·0	

Boom Period 18 seconds. 1 mm. = 0″·59.

VICTORIA, B. C.

F. N. DENISON, SUPERINTENDENT.

No.	Date 1914	P.T. Comm.	L.W. Comm.	Max.	End	Max. Amp.	Durat.	Remarks
		h m	h m	h m	h m	mm.	h m	
1398	Oct. 1		6 49·6		7 14·0	0·2	0 24·4	
1399	" 3	17 30·6	17 51·2	17 57·7 17 59·0	20 17·4	7·5 7·4	2 46·8	
1400	" 3	22 30·1	22 49·9	22 59·6	0 46·1	1·5	2 16·0	
1401	" 6	21 24·9?	21 32·4	21 33·9	21 46·9	0·2	0 22·0	
1402	" 8	12 37·4	12 45·4	12 46·4	12 53·4	0·2	0 16·0	
1403	" 9	3 26·7	3 39·7	3 42·7	4 5·7	0·2	0 39·0	
1404	" 13	9 45·4?	9 45·4?	9 47·9	9 51·4	0·15	0 6·0	
1405	" 14	14 27·9	14 42·9	14 46·9	15 1·9	0·5	0 34·0	
1406	" 17	7 4·9	7 14·9	7 16·9	7 26·9	0·1	0 22·0	
1407	" 21	16 33·3?	16 39·3	16 41·8	7 4·3	0·1	0 31·0	
1408	" 22	6 51·1?	6 56·1	6 57·1	7 3·1	0·4	0 12·0	
1409	" 23	6 43·3	S 6 51·8 L 7 3·8	7 10·3	8 54·8	1·0	2 11·5	
1410	" 25	19 33·3?	19 38·8	19 40·8	19 51·3	0·2	0 18·0	
1411	" 27	4 3·9	4 10·9	4 12·9	4 31·9	0·1	0 28·0	
1412	" 27	16 31·0?	16 42·0	16 43·5	17 5·0	0·1	0 34·0	
1413	" 28	0 52·9?	1 11·9	1 13·9	1 39·9	0·15	0 47·0	
1414	" 29	7 58·3	8 2·8	8 3·8	8 10·8	0·1	0 12·5	
1415	Nov. 7	7 24·9	7 28·9	7 30·4	7 44·9	0·1	0 12·5	
1416	" 8	12 2·0	12 4·0	12 6·0	12 24·0	0·2	0 22·0	
1417	" 8	12 34·0	12 37·0	12 39·5	12 56·0	0·3	0 22·0	
1418	" 8	20 46·0	20 47·0	20 50·5	21 4·0	0·3	0 18·0	
1419	" 10	7 15·2	7 16·7	7 18·2	7 39·2	0·1	0 24·0	
1420	" 10		11 9·7	11 10·7	11 18·2	0·7	0 8·5	
1421	" 13	0 25·3	0 50·8	0 52·3	1 7·3	0·3	0 42·0	
1422	" 18	9 56·3	S 10 0·8 L 10 8·3	10 14·8	10 55·8	1·0	0 59·5	
1423	" 22	8 38·4	S 8 46·4 L 9 3·4	9 10·3	9 41·3	0 2	1 3·0	
1424	" 24	7 57·8?	8 25·3	8 28·3	8 42·3	0·2	0 44·5	
1425	" 24	12 4·8	S 12 13·3? L 12 13·8	12 14·3 12 19·8	14 44·8	2·5	2 40·0	
1426	" 27	4 26·2	4 27·2	4 27·7	4 29·7	0·3	0 3·5	
1427	" 27	15 24·7	15 27·7	15 31·7	15 51·2	0·2	0 26·5	
1428	" 28	11 17·3	S 11 24·3 L 11 35·3	11 41·8	12 30·8	0·2	1 13·5	

Period 18 seconds. 1 mm. = 0″·54

J. V.

ASTRONOMICAL NOTES

Atomic Disintegration. — The fact that the atom of an element can undergo an internal change, referred to as disintegration, as the result of which the atom assumes entirely new properties, produced a complete revolution in scientific thought. Yet that direct change is comparatively simple when compared with the branching of the disintegration series, shown by radium-C, thorium-C, and uranium. Thorium-C was the example first discovered. So far as we know at present, the process is that each atom of a homogeneous collection of thorium-C atoms has the choice of emitting either an α particle or a β ray. What action pulls the trigger to let off one or the other we do not know. Whatever the mechanism, it always happens that thirty-five per cent. of the atoms give off α rays, and that the remaining sixty-five per cent. give off β rays. In the case of radium-C it happens that only 0·03 per cent. give α rays, while 99·97 per cent. give β rays. Evidence has also been obtained by Marsden and Wilson that actinium-C likewise undergoes a dual disintegration. The case of uranium is unique. In all the above examples the atom has the choice of two different kinds of rays, but in this case the choice is between two β rays of different ranges, that is, that the quantity of energy liberated in the different modes is dissimilar. The chemical properties of the resulting products are in this case identical, but their stability is very different, and as a consequence, these latter elements break up at very different rates. — *Knowledge*, No. 555.

The Constitution of the Atom. — The subject of the constitution of the atom has come into extreme prominence — great advances have been made — while much light has been thrown on the ultimate structure of matter. Years ago, during the persistent and systematic fractionation of yttrium, I explained that I had succeeded in separating the atoms of the so-called

element into groups ; these groups undoubtedly exhibited different phosphorescent spectra and presumably had different atomic weights — although from the chemical point of view all the groups behaved similarly. I concluded that, of the lines and bands of the compound spectrum of an element, some are furnished by certain atoms and some by others. I pointed out that this was not likely to be an isolated case ; that probably in all so-called elements the whole spectrum does not come from all the atoms — that different spectral rays come from different atoms, which may be interpreted to mean that there are definite differences in the internal motions of the several groups of which the atoms of a chemical element consist. I ventured to suggest a possible explanation of these facts, based on the assumption that acting on the original *protyle* were two forces — one of the character of Time, accompanied by a lowering of temperature, while the other, swinging to and fro like a pendulum, and having periodic cycles of ebb and flow, rest and activity, would be intimately connected with the force of electricity. I arrived at a presentation of the elements on a lemniscate path which seemed to me to throw some light on the question of their genesis. My researches seemed to show that the persistance of the ultimate character, the eternal self-existence, the fortuitous origin of the chemical elements, could no longer be regarded as satisfactory.

Apparently bodies exist which possess close upon the same atomic weights and combine in definite proportions with other substances and yet exhibit certain minute differences. For these substances, which are capable of being isolated and identified, I suggested the name "meta elements." Thus there appears to me to be a gradation of molecules of different ranks between the atom and the compound — and these aggregations of atoms in certain circumstances might well pass for simple elementary bodies.

In recent years the old idea of the ulimate atom as a solid particle, sperical or otherwise, has slowly, almost imperceptibly, given way to the more rational conception of a minute planetary or "Saturnian" system of dazzling complexity ; the conception is many minded, aided here and there by facts that failed to fall in with the old lines of thought. Among the most prominent

men through which the new conception has come to light, we have Kelvin, Stoney, Thomson, and, more recently, headed by Sir Ernest Rutherford, a host of vigorous workers in the new science of radio-activity, who have built up a conception of atomic physics often "hard to be understood" but that probably is a move in the right direction. Sir Ernest Rutherford supposes the atom to be composed of a nuclear positive charge, exceedingly small compared with the sphere of action of the atom, and consisting of a number of unit charges. Surrounding this nucleus is an external shell in which a number of separate negative electrons are distributed. Professor Soddy — whose name is closely associated with that of Sir Ernest Rutherford — is one of the earliest workers in radio-activity, and has developed a theory of the chemistry of the ratio-elements based upon the periodic law and a modified form of lemniscate spiral where the existence of *psuedo* elements having slightly different atomic weight but identical chemical properties are set out. These "isotopic" elements occupy the same place in the Periodic Table. He has thus arrived, by a totally different path from the one I travelled, at the conception of an element having atoms of different weight though chemically identical. The theory has recently received some confirmation by the analyses of the lead that is found in the minerals pitchblende, thorianite, etc. In my own laboratory a spectroscopic examination of the lead from Cornwall pitchblende has shown traces of thallium not found in pure assay lead; the unexpected presence of this element may have some bearing on the slightly different atomic weight values recorded for the lead extracted from the radio-minerals.

Without risking a charge of being unduly optimistic I think I may believe we are on the brink of striking developments in our knowledge of the structure of the elusive atom. Whatever may be the outcome of researches now prosecuted with so much zeal and success, I feel that Addison was speaking with the voice of prophetic Truth when, more than a hundred years ago, he said: "Every atom is a standing miracle and endowed with such qualities as could not be impressed upon it by a Power and Wisdom less than infinite." — Sir Wm. Crookes, Anniversary Address, November 30, 1914, *Royal Society Proceedings*, No. A 625.

J. R. C.

NOTES AND QUERIES

Communications are Invited, Especially from Amatuers. The Editor will try to Secure Answers to Queries.

Query

What must one more especially guard against in trying Foucault's experiment?

A few of us tried it recently with some wonderful results, as follows:—

1st.—The world rotates from west to east.

2nd.—It makes slightly more than a quarter rotation in about one hour.

3rd.—It then hesitates and decides to rotate in the other direction at a much slower pace.

4th.—After resting over night we discovered that it had finally decided to rotate from east to west but outrivalled Jupiter in speed.

Our weight was about 4 lbs., and though not exactly spherical yet horizontal sections would have been circles. We used fine twine for suspending the weight and dry sand to show the path, length of pendulum about 14 ft. and swing about 8 ft. released by burning.—T. H. Wingham, (Hamilton).

Answer

I think the experiment failed (though perhaps the demonstration of such wonderful results should hardly be considered a failure!) on account of the fine twine, which would produce torsional motion; the insufficient weight, which would not keep the pendulum swinging satisfactorily with moderate initial displacement; and to the small length of the pendulum.

A brief description of the pendulum used by the writer at the University of Toronto, on various occasions, very seldom without success, may be of interest. The bob is of selected cast iron, six inches in diameter and accurately turned to a sphere, and weighing about 25 pounds. It is suspended by fine piano-wire, as small as can be used with safety. No. 27, S. W. G.,

0·0164 inch in diameter is found satisfactory. In the room where the pendulum is generally mounted the wire is about 9·8 metres = 32·2 feet long, but I think the experiment would succeed with a shorter wire. A steel pin about two inches long projects from the lower portion of the bob, carefully made to be in line with the suspending wire. This steel pin ploughs through the sand-ring, which is about 0·8 metre in diameter. The bob is pulled aside through about a metre and held there by a string about its equator. When perfectly at rest it is released by burning the string. The upper end of the suspending wire passes through a fine hole in a brass plate, which is firmly screwed to the ceiling.

DR. GLASHAN ON "HOW KNOWLEDGE GROWS"

In the present number, the veteran educationist, Dr. J. C. Glashan, gives the concluding portion of his paper on "How Knowledge Grows," read before the Centre at Ottawa. The cultivation of astronomy dates back to very early times, and we are not surprised to find the threads of its development continually appearing in the fabric of scientific thought as it was woven during the passing centuries. Such a subject as that chosen also necessarily deals with various philosophical ideas, and though perhaps some readers may feel inclined to disagree with some of the views expressed, all will agree that the author has a comprehensive grasp of the great subject which he has so pleasingly outlined.

NOTES ON DELAVAN'S COMET, SEPTEMBER-OCTOBER, 1914

The Editor is pleased to publish the following notes of observations on Delavan's Comet by Mr. A. F. Hunter, M.A., who is Secretary of the Ontario Historical Society, with office in Toronto, though still making Barrie his home.

September 20, 1914, 8 p.m. at Barrie, I observed Delavan's

Comet, of the fourth magnitude, or thereabout. It was brought to my attention by my nephew, William Harding Carr, who had observed it first on the night of September 16. Its position to-night, under the "Dipper," is a little to the right of the line through the pointers (*i. e.*, α and β of Ursa Major).

It was also visible next morning from 4 to 5 a.m.

September 25, 7.45 p.m. at Toronto. It has moved a few degrees to the west, its position to-night, under the "Dipper," being in line with γ and δ of Ursa Major. It is rather better defined than on September 20, but the nucleus is still of the fourth magnitude. The tail is less diffuse than on September 20, and slightly longer.

September 27, 7.45 p.m. at Barrie. Its position is about two degrees further west than on the night of the 25th.

Next morning, in the east, and higher above the haze of the horizon than last night, it showed a little stronger than the fourth magnitude. Its tail now has a distinct length of about one degree visible to the naked eye.

October 1, 8.15 p.m. at Barrie. The Comet has moved rapidly west, its position being now in line with Polaris and γ of Ursa Major.

October 2, 4.30 a.m. at Barrie. In the short interval since last night it has moved perceptibly toward the sun, being now in line with Polaris and δ of Ursa Major. In size the nucleus is now of the third magnitude, though less intensely brilliant than a star. Its tail is broad.

October 11, 7 p.m., and later in the evening at Barrie. The Comet is quite visible in the northwest. Its position is now in line with α and γ of Ursa Major, and distant from γ about twice the distance between α and γ. Its tail is now visible for from 4 to 5 degrees in length.

October 12, 7.30 p.m. The Comet is quite distinctly seen from a moving train in King Township near Aurora.

October 24, 6.30 p.m., 7 p.m., etc., at Barrie. Its position is much beyond the "Dipper" now. The line from the Comet

to Polaris is outside of the constellation altogether, and much further west. Its position is about twice the length of the "Dipper" handle (δ and ζ of Ursa Major) from the most westerly star of the group, *i.e.*, η of Ursa Major. It has about the third magnitude. Its tail is now longer, being visible for about ten degrees, notwithstanding the light of the moon which is near the first quarter.

October 27, 5 a.m. at Barrie. The Comet is visible low down in the east, almost in line with the base of the "Dipper," *i.e.*, β and γ of Ursa Major. Owing to its position in the haze of the horizon, its tail is not traceable for more than ten degrees.

AN INTERESTING OBSERVATION OF LIGHTNING

Professor W. H. Day, of the Ontario Agricultural College, Guelph, and president of the Centre of R.A.S.C. there, under date December 2, 1914, writes as follows:—

I have been much interested in Mr. Steadworthy's photographs of lightning strokes and also his article. It reminds me of a lightning phenomenon which I witnessed one day last June. I had never heard of such a form of flash before, although I learn that they are occasionally observed.

On this particular day I was motoring from Whitby to Toronto. Off in the north-east lay a heavy bank of thundercloud, south and west of the cloud and also above it the weather was fine and the sky remarkably clear, there being no sign of clouds. As we watched the cloud and the flashes playing about it we suddenly noticed one start from the upper left hand corner and proceed obliquely upward into the clear sky towards the west. The flash was strong and bright at the cloud end and it diminished in intensity toward the upper end. There were two of us in the car and we observed four very long flashes of the kind just described and some other smaller ones extending only a short distance up from the cloud.

THREE INTERESTING CLIPPINGS

The first one is from *Science* for September 11, 1914, and is a description of a display of the aurora seen on July 4 last at Nett Lake, Minnesota, Latitude 48° N., by Albert B. Reagan.

NORTHERN LIGHTS IN SUMMER

I live at Nett Lake, Minnesota, 140 miles northwest of Duluth and 38 miles south of Fort Frances, Ontario, Canada. On the night of July 4 there was a fine display of northern lights (aurora borealis). It was as fine a display as is seen in this section even in the coldest months. There were spires and rolls of light and a bow of light which covered the whole northern sky and towards midnight reached nearly to the zenith.

* * *

The second is a desciption of sunrise at the equator. It is taken from the December *American Magazine*, and was written by Stewart Edward White when on a lion hunt in German East Africa near its northern boundary.

SUNRISE UNDER THE EQUATOR

Each morning then, for some time I got up in the black night, ate my solitary breakfast by the flicker of a fire and then, just as the first milky gray was peeping into the darkness, I would start out for a walk. The ground was not to be seen at all, nor the objects near the ground, only the tops of trees like ghosts. We stumbled and moved slowly, feeling our way. All about us we could hear beasts snorting softly at us, like mettlesome horses, stamping on the earth, or perhaps we heard the short swift rush of them as they dashed away. Only when they moved could we see them, phantom bits of the same dim distance of all the rest of the world. They were puzzled at us, and curious, and very near.

And all the time the flames were spreading in the sky, the fierce, hot, red and copper and orange flames, of the African sunrise. They reflected on the earth. We could see a little better, guess a little more. Then all at once some dilatory god threw over the switch, and it was light!

Never did I become accustomed to the magic of this phenomenon. Whenever anybody, white or black, happened to be near me, I remarked upon it to him; and generally gained slight response.

* * *

My third clipping is from a Toronto daily newspaper and is a Canadian Press Despatch from China. From it we learn that the President of the young republic, though modern in many things, is not yet free from the ancient superstition regarding the winter solstice.

WORSHIP AT THE WINTER SOLSTICE

Pekin, December 23, 1914. -- President Yuan Shi Kai at sunrise to-day appeared before the Altar of Heaven in the Chinese city and revived the worship of Heaven at the winter solstice, an observance neglected since the passing of the Manchu dynasty in 1911. In this the President of the Republic took upon himself a function and rite which in the past always has been reserved to the Emperor of China in his capacity of "T'ien Tsze," or Son of Heaven.

Surely this is turning the hands of the clock backwards. Yuan had better be a son of the people; we have had too much trouble with sons of heaven recently. It may prove interesting, however, to learn the nature of the performance; and I find the following description of the ceremonials in Lockyer's *Dawn of Astronomy*, being quoted from Williamson's *Journeys in North China*:—

The most important of all the State observances of China is the sacrifice at the winter solstice, performed in the open air at the south altar of the Temple of Heaven, December 21st. The altar is called Nan-Tan, 'sound mound' or Yuenkieu, 'round hillock' -- both names of the greatest antiquity.

Here also are offered prayers for rain in the early summer. The altar is a beautiful marble structure, ascended by twenty-seven steps, and ornamented by circular balustrades on each of its three terraces. There is another on the north side, of somewhat smaller dimensions, called the Ch'i-ku-t'an, or altar for prayer on behalf of grain. On it is raised a magnificent triple-roofed circular structure 99 feet in height, which constitutes the most conspicuous object in the *tout ensemble*, and is what is called by foreigners the Temple of Heaven. It is the hall of prayer for a propitious year, and here, early in the spring, the prayer and sacrifice for that object are prosecuted. These structures are deeply enshrined in a thick cypress grove, reminding the visitors of the custom which formerly prevailed among the heathen nations of the Old Testament, and of the solemn shade which surrounded some celebrated temples of ancient Greece.

The south altar, the most important of all Chinese religious structures, has the following dimensions: It consists of a triple circular terrace, 210 feet wide at the base, 150 feet in the middle, and 90 feet at the top. In these, notice the multiples of three:--$3 \times 3 = 9$, $3 \times 5 = 15$, $3 \times 7 = 21$. The heights of the three terraces, upper, middle and lower, are 5·72 feet, 6·23 feet, and 5 feet respectively. At the times of sacrificing, the tablets to heaven and to the Emperor's ancestors are placed on the top; they are 2 feet 5 inches long, and 5 inches wide. The title is in gilt letters; that of heaven faces the south, and those of the ancestors east and west. The Emperor, with his immediate suite, kneels in front of the tablet of Shang-Ti and faces the north. The platform is laid with marble stones, forming

nine concentric circles; the inner circle consists of nine stones, cut so as to fit with close edges round the central stone, which is a perfect circle. Here the Emperor kneels, and is surrounded first by the circles of the terraces and their enclosing walls, and then by the circle of the horizon. He thus seems to himself and his court to be in the centre of the universe, and turning to the north, assuming the attitude of a subject, he acknowledges in prayer and by his position that he is inferior to heaven, and to heaven alone. Round him on the pavement are the nine circles of as many heavens, consisting of nine stones, then eighteen, then twenty-seven, and so on in successive multiples of nine till the square of nine, the favourite number of Chinese philosophy, is reached in the outermost circle of eighty-one stones.

The same symbolism is carried throughout the balustrades, the steps, and the two lower terraces of the altar. Four flights of steps of nine each lead down to the middle terrace, where are placed the tablets to the spirits of the sun, moon, and stars and the year god, Tai-sui. The sun and stars take the east, and the moon and Tai-sui the west: the stars are the twenty-eight constellations of the Chinese zodiac, borrowed by the Hindoos soon after the Christian era, and called by them the Naksha-tras; the Tai-sui is a deification of the sixty-year cycle.

THE JOURNAL TO APPEAR MONTHLY

Beginning with the next number, the JOURNAL will appear monthly. In the very first number, (January-February, 1907) the hope was expressed that it would become a monthly, but heretofore it has not been possible to carry out this proposal. However, the advantages of more frequent and prompt publication are so great that an effort will be made to prepare rather smaller numbers and have them issued by the first of each month, omitting two summer months. The members are urged to send in reports of observations or other notes of astronomical interest. The "Notes and Queries" department is a broad one and contributions are cordially invited.

C. A. C.

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